Sound Shizuku Composition: a Computer-Aided Composition System for Extended Music Techniques

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Abstract

Abstract: *We discuss in this paper a new environment for computer aid musical composition which is designed to create works centered on the creative use of instrumental extended techniques. The process is anchored on computational techniques to retrieve musical information via audio descriptors. We developed an analytical process, based on the extraction of spectral characteristics of a Sound DataBase (SDB), and on supporting the compositional planning as follows: relate statistical measures to the spectral behavior of specific execution modes of various instruments contained in the SDB. The result of the process is a palette of possibilities that assists the composer decisions regarding to the desired orchestration to be applied in a musical piece. The paper presents then the motivation and context to develop the environment, describes and characterizes the audio descriptors that have been studied, presents the computer system architecture and discusses the results obtained with Sound Shizuku.*

Keywords: *Composition. Computer-Aided Orchestration. Audio Descriptors. Extended Techniques. Interdisciplinary Music Computation.*

I. Introduction

Among the contemporary music compositional techniques, some of them can touch upon the control factors related to musical timbre [1] and significantly alter the spectral characteristics of each single note heard. It could be compared to a palette of color where mixed extended instrumental techniques produce new shades and, finally, create new orchestral sounds. In line with the use of timbre as a potential space for composition, there is an increasingly concern with

[1]The issues related to the term 'tone' as used in this paper, exceeds the definition by 'exclusion to' that timbre is an identification of property and distinction, whose sound sources have the same intensity and pitch. We attribute the term 'timbre' a spectral morphological identity, as discussed by Smalley [37] .

getting more refined and particular timbre results, both for the compositional planning and for the instrumental/vocal realization. The idea of timbre as a 'metadimension' [14, p. 45] shows the interest to consider it not as a simple 'color' but as a potential space for integration of other musical features and thus become the central focus of the composition. From the artistic point of view, the timbre is a concept linked to the *modus operandi* of musical language, concurrent to aesthetics and musical form. Nevertheless there is still a fundamental issue centered on the difficulty of relating to a 'musician qualitative intuition' on timbre with a 'quantitative assessment' of possible categories of measures and objective analysis of the musical timbre behavior [5, p. 162].

This paper establishes a dialogue between the study of musical timbre, as poetic and musical approach, to a scientific point of view. More specifically, we work with recent studies on music information retrieval based on spectral content that are the inner microstructures of musical timbre and therefore might help the development of a more refined and conscious compositional planning. This view has its origins in the pioneering research of Hermann von Helmholtz whose treatise related timbre to the presence and the magnitude of spectral components with respect to its fundamental component [15]. This study provided important subsidies to timbre analysis focused on the spectral characteristics of the sound [26, 31, 13]. Other researches from Berger [4] and form Wedin and Goude [41] pointed to a correlation between the accuracy of timbre recognition with the attack and decay time of the sound source. As for Pierre Schaeffer, the timbre of a sound is perceived by the variation of its spectral behavior and its evolution in time [28]. Schaeffer was the pioneer by separating the physical phenomenon of the sound of his own perception phenomenological.

Based on these concepts we present a man-machine interaction methodology that connects computer aid sound analysis with the symbolic notation of a music score. We conducted a study on musical information retrieval via low-level audio descriptors that are centered on feature extraction of sound frequency spectrum. In this sense, using audio features as composition architectural tools, two approaches to aid the compositional planning were developed: *a)* extract from sound frequency spectra specific features *b)* relate them to modes for the extended instrumental techniques, including transcription to symbolic music information and music orchestration. For this goal we have developed an virtual analytical environment that recommends orchestral sonorities called *Sound Shizuku Composition – SSC*. To present this environment and its compositional implications, in Section II we discuss the main stages of the sound analysis and music orchestration assisted by computer. On Section III practical results are briefly discussed. Finally, we conclude our article in Section IV discussing forthcoming projects.

II. Architecture of the Methodology

The scope of the computer-assisted music orchestration system presented here is to apply audio descriptors to provide a pallet of contrasting timbre variations. The goal is to produce a refined blending of sounds derived from set of extended techniques. Therefore the creative process relates sounds, described by audio descriptors, and instrumental settings to transcriptions of these relations into a music score. Finally, the transcriptions improve the original compositional planning in face of the computer aid orchestration. The first step developed here was to build 'Sound Mixtures' that can be defined as computer simulations to generate audio files that will expand possibilities of instrumental mixes. Sound Mixtures, are generated by superimposing modes of playing, articulations and various extended instrumental techniques storage as audio samples in the Sound DataBase (SDB).

Secondly the mixtures are analyzed with audio descriptors in order to extract their related spectral features. Section i presents the audio descriptors used to process that extraction. Figure 1 is the general outline of the proposed methodology in our research into computer-assisted music orchestration.

i. Audio Descriptors Technical Definitions

In this section i we discuss the use of audio descriptors to provide sound analysis capability to the music orchestration system. We introduce only audio descriptors that were studied in our research. The scientific knowledge area on this subject is called Music Information Retrieval or simply MIR [6, 7, 29, 38]. Studies on MIR use mathematical functions, supported by statistical measurements and psychoacoustic models to proceed the so-called audio features extraction. According to [22, p. 01] the methodology to describe the characteristics of a sound signal have been proposed by the scientific community to recognize patterns of speech and musical instrument classification. These procedures are also significant tools on the context of musical composition and orchestration. Several methods for analyzing the spectral content of digitized audio signals are performed by Short-Time Fourier Transform or STFT, which is defined as follows by Sheh and Ellis [30, p. 02]:

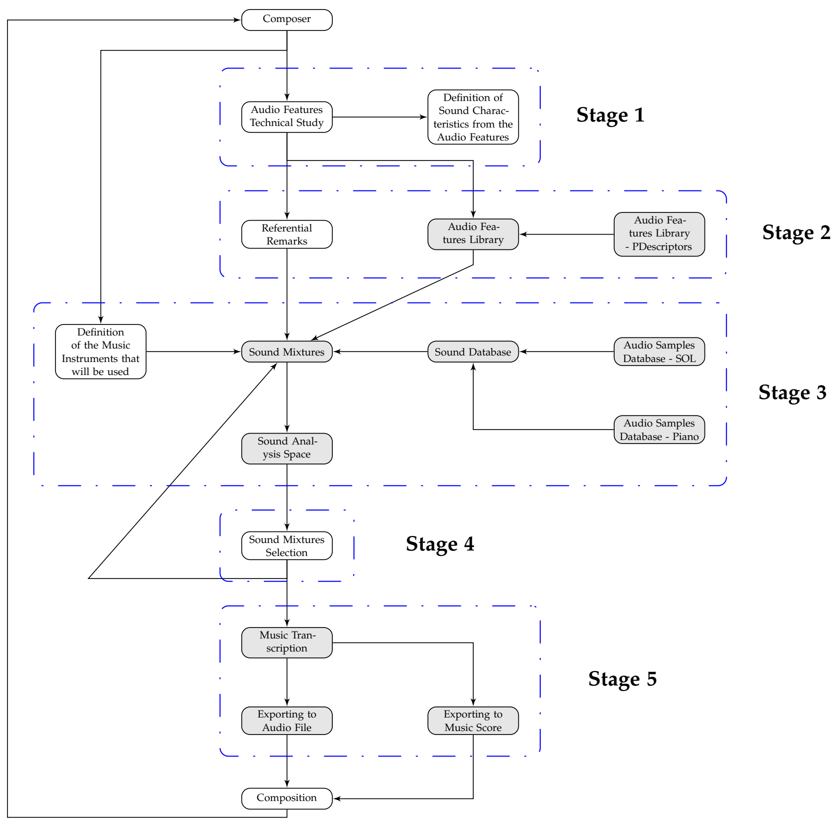


Figure 1: *General scheme of the computer-assisted music orchestration* Sound Shizuku Composition - SSC. *The gray blocks represent the computational flow data for sound analysis. The white blocks represent user interaction with the system itself. The dotted and dashed blocks comprise the tasks of each of the five steps of our methodology architecture.*

$$\mathbf{STFT}_{[\mathbf{k},\mathbf{n}]} = \sum_{m=0}^{N-1} x[n-m]w[m]e^{-j2\pi km/n} \tag{1}$$

Table 1: *Summary of the audio features.*

Feature	Definition	Sound Correlative	Possible Application
Spectral Centroid	Center of the Mass	Brightness/Opacity	Sound Detection Centroidariation
Spectral Standart Deviation	Spectral Bandwidth	Sound Mass	Spectral Bands Equalization
Spectral Skewness	Asymmetry or Obliquity	Hot and Rounded/Bright and Penetrating	Detection of percussion instruments
Spectral Kurtosis	Flattening of the Distribution	Noise	Transient Detection
Spectral Flux	Time Attack	Attack	Detection of Sound Events
Spectral Flatness	Ratio of Geometric Mean with Arithmetic Mean	Noise/Tone	Noise Removal
Spectral Irregularity	Difference Magnitude Spectrum	Velvety and Smooth/Rough and Ribbed	Spectral Band Equalization
Spectral Roll-Off	Spectral Slope Envelope	Roughness	Mastering Voice and Music
Odd-to Even Ratio	Quotient of the Magnitude of the Spectral Components	Nasal/Soft	Detection of Musical Intensities
RMS Energy	Root Mean Square of the Energy	Strong/Weak	Detection of Sound Intensities
Loudness	Auditory Sensation of Sound Intensity	Strong/Weak	Sound Intensity Perception
Zero-Crossing Rate	Signal Changes in Time	Noise	Sound Noise Detection
Spectral Decreasing	Energy Spectrum	Percussion Sounds	Detection of Percussive Sounds
Temporal Centroid	Temporal Center of the Mass	Percussion Sounds	Detection of Percussive Sounds
Spectral Chroma	Spectrum Analysis by Musical Pitches	Tonality	Harmony Identification

where k indexes the frequency axis with $0 \leq k \leq N-1$, n is the short-time window center, and $w[m]$ is an N-point Hanning window.

From the widespread view in the area of MIR, audio descriptors are tools for sound analysis and most of them are represent by one-dimensional curves. As pointed out by Rimoldi [27, p. 01], the audio features are useful tools for a taxonomy of features related to the spectral content of the analyzed sound signal even though with their reductionist characteristics in relation to the analyzed object. Such features can be correlated and not necessarily equivalent with subjective attributes of the perception of the sound signal, such as 'brightness', 'opacity', 'roughness', 'noisiness', 'softness', among others.

To our research we use a set of fifteen audio features: Spectral Centroid [39, pp. 460-461], Spectral Standard Deviation [9, 27], Spectral Skewness [9], Spectral Kurtosis [1], Spectral Flux [22, 24], Spectral Flatness [8, p. 01], Spectral Irregularity [16], Spectral Roll-Off [19, p. 47], Odd-to Even Ratio [22], RMS Energy [17, p. 113], Loudness [42, 10, 20, 40, 25], Zero-Crossing Rate [24, 21], Spectral Decreasing [18], Temporal Centroid [23] and Spectral Croma [11, 12]. Such statistical measures estimate particular characteristics of a digital audio signal. As already pointed out, audio descriptors are powerful tools for the creation of a taxonomy of spectral characteristics. This taxonomy can be correlated but not necessarily equivalent to the subjective attributes of the human perception. Table 1 summarizes the main highlighted points for the audio descriptors. In it, we summarized the presentation of the features with their possible applications.

ii. Sound DataBase - SDB

The audio samples used to generate Sound Mixtures belong to two databases compiled by Ballet *et. al* [2] and Barbancho *et. al* [3]. Such samples have durations between five to seven seconds in .aiff audio format. In Ballet research called Studio OnLine or SOL the repository of instrumental sonorities relates to 'some aspects of the sound of contemporary instrumental music' [2, p. 124]. In total, the SOL database has 16 musical instruments such as accordion, tuba, bassoon, clarinet, trumpet, contrabass, alto saxophone, flute, guitar, harp, horn, oboe, trombone, violin, viola and cello. The collection of samples includes some extended instrumental techniques.

The database belonging to Barbancho [3], focuses on piano sounds. The research covers an extensive study on piano sounds, from a single note to a whole chord with up to ten simultaneous notes. There are several recordings of the piano in different registrations, intensities in *staccato* and *ordinary* playing techniques with the presence or absence of the damper pedal. In both databases, there are three different musical dynamics: *pianissimo* or *p*, *mezzo-forte* or *mf* and *fortissimo* or *ff*. In the current version of our research we chose to use the piano audio samples playing only the one single note. The current version of our database (SDB) has an approximate size of 30 GB[2]. Following Section iii describes the main steps that established the construction the sound analysis and orchestration environment, named as *Sound Shizuku Composition*

iii. Sound Analysis Environment - *Sound Shizuku Composition - SSC*

The *Sound Shizuku Composition* or *SSC* [3] was built in modules that provide orchestration cues using the SDB, described in Section i. *SSC* was developed in Pure Data (PD) using a library of audio descriptors developed by Monteiro [21] at the Interdisciplinary Nucleus for Sound Studies (NICS). Next Subsections discuss each of the modules and all the other computational routines that was also implemented in Pure Data. There are seven modules as follows:

- Module 1 - Selection of musical instruments and the desired instrumental techniques
- Module 2 - Define orchestration blending to be evaluated by audio features
- Module 3 - Calculation of orchestration algorithm of sonorities
- Module 4 - Selection of the audio descriptors
- Module 5 - Analysis of sonorities via audio descriptors
- Module 6 - Interaction and choice of sound mixtures arranged in the GUI visual cues
- Module 7 - Selection of output formats of sound mixtures in audio format and musical score transcription

iii.1 Module 1 - Selection of musical instruments and instrumental techniques

In the first stage the composer defines the desired musical instrumentation from a total 16 choices of musical instruments. Choices of instrument are repeated in such way that a selection of an instrument is followed by the choice of an instrumental techniques. The current version of *SSC* does not allow selection of the same instrument, that is, the system enables only one flute, one clarinet, one trumpet, one tuba etc. Figure 2 illustrates the Step 1.

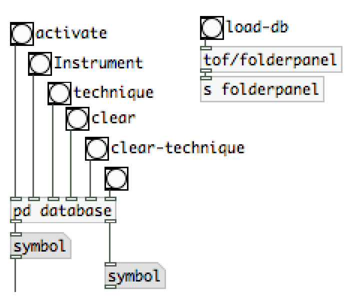


Figure 2: *Figure of Module 1. To startup the system is necessary to load the database using the* load-db *in the upper right corner.*

iii.2 Module 2 - Define orchestration blending

In this module, the composer is able to restrict the amount of Sound Mixtures (SM) to reduce computer calculation when search and analyse mixtures. We also implemented a restriction

[2]Because of its size, we can not attach the sound database. It is suggested to contact the author to get the current version of the sound database. email: mieysimurra@gmail.com

[3]The term *Shizuku* is Japanese for water drop.

algorithm for searching orchestration solutions based on the presence of a pitch profile using the Spectral Chroma, audio descriptors. This procedure ensures that the SM are restricted to a certain pitch or at least to the presence of a specific musical time. It is possible to use the pitch profile to calculate a percentual pitch presence. The algorithm calculates the presence in the range $[0, ..., 1]$. When presence is 100 %, the search algorithm process the orchestral indication with the greatest pitch influence. If the user do not indicate the presence of pitch the search algorithm performs the selection of the SM randomly. This second possibility was accomplished with the use of the function *urn*, in Pure Data. Next, Figure 3 illustrates the module 2 showing the quantity of orchestral blending, given specific pitch and its percentage of presence.

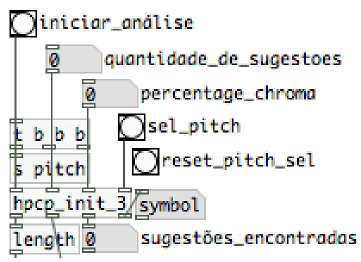


Figure 3: *Figure of module 2 of the* SSC *system*

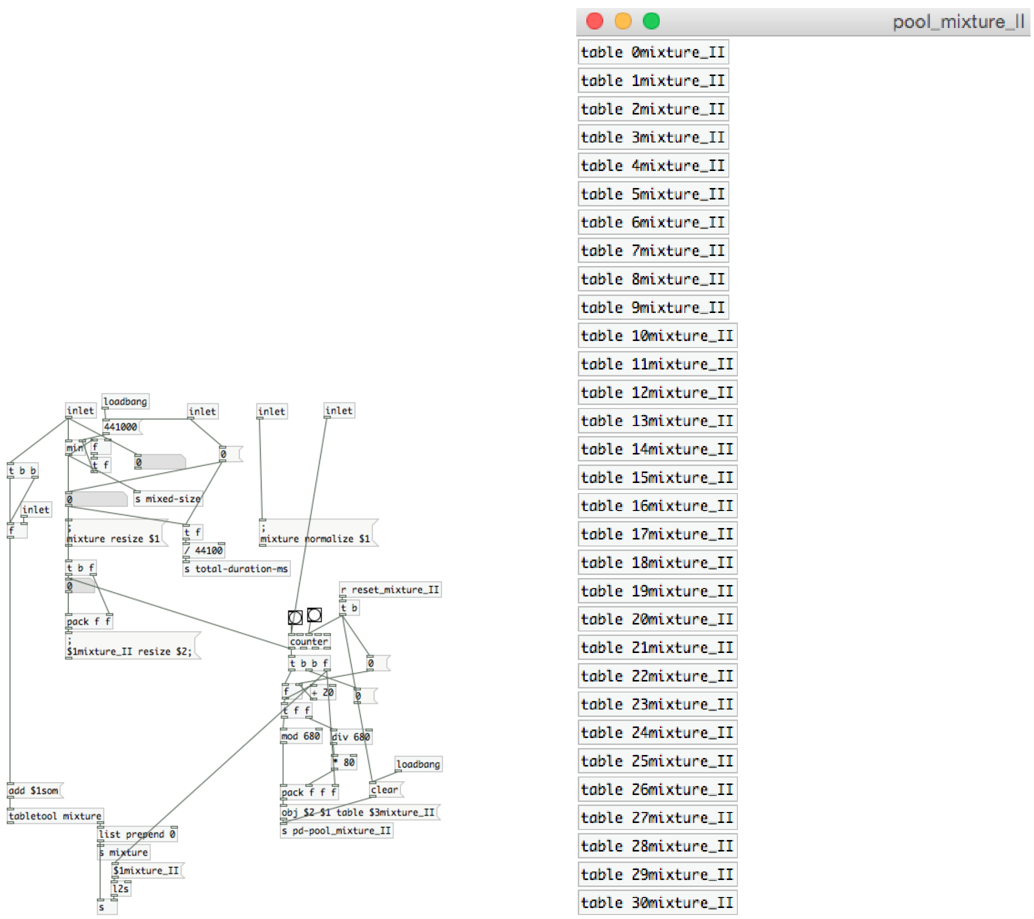
iii.3 Module 3 - Orchestration

The orchestration step uses the pitch presence, defined in the previous section, to perform overlays of audio files from the sound database (SDB). This routine is performed using the object *tabletool*, from *TimbreID* library, developed by William Brent [4]. Each audio file is edited so that the overlapping is performed on files with the same length. For this, we use the object *min*, from Pure Data (PD), which identifies the smallest window of the data collected. The overlays are rendered and stored in tables that will be used to extract the audio features. Figure 4a presents the overlay algorithm of audio samples defined by the Module 1. The Figure 4b, represents the audio samples *corpus*.

iii.4 Module 4 - Selecting Audio Features

After establishing the *corpus* of sound mixtures, sound analysis is conducted. In total, it is used a set of four pairs of features which are arranged in a two dimensional space, a coloured graphic display. As discussed in Section i, audio descriptors project the retrieved information of the sound spectrum to one-dimensional curves. However, as discussed in the Introduction, timbre is a perceptual feature which has several parametric dimensions. In order to help the composer to expand the analysis scope on specific sonic characteristics, a set of four pairs of audio descriptors is present in a graphic display. This tool enabled a refined detailing of various sound characteristics. Section i then presents the available audio features in the current stage of our system. Figure 5 illustrates the selection of the four pairs of audio features. Indications 'x' and 'y', below each feature represent their disposal in the operating interface of Sound Mixtures performed by Module 3.

[4]For more information about the *TimbreID*, see: `<http://williambrent.conflations.com/pages/research.html.>`



(a) (b)

Figure 4: *Figure for the audio samples overlays. In Figure 4a, the process is performed by the object* tabletool*, from the* TimbreID *library. Figure 4b, the overlays are stored in the* corpus *named* mixture_II*. The* corpus *will be analyzed by audio features in Module 4.*

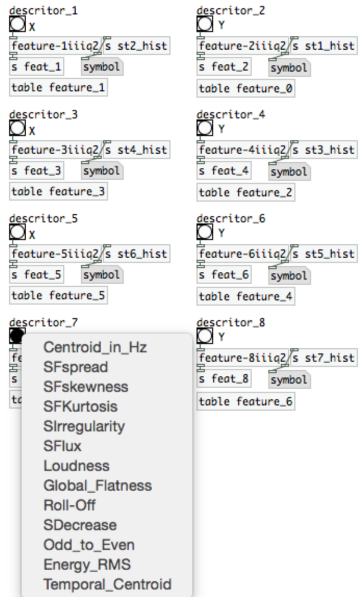


Figure 5: *Figure of the Module 4 in which the user can select the set of four pairs of audio features that will analyze the sound mixtures.*

iii.5 Module 5 - Sound Mixtures Analysis

In Module 5, the system performs the sound mixtures analysis via audio descriptors. The features are based on the suitable *PDescriptors* library developed at NICS/UNICAMP [21]. It calculates the mean of the extracted values of each audio feature. These means are accumulated in a list of data to be arranged in a space for exploration and analysis. Figure 6a represents one of the four pairs of the features chosen in module 4. In this *patch* the data analysis are collected. The mean of the data are stored in sub-module *pd accum-symbol*. These means are arranged in the space of operation which will be described in Module 6.

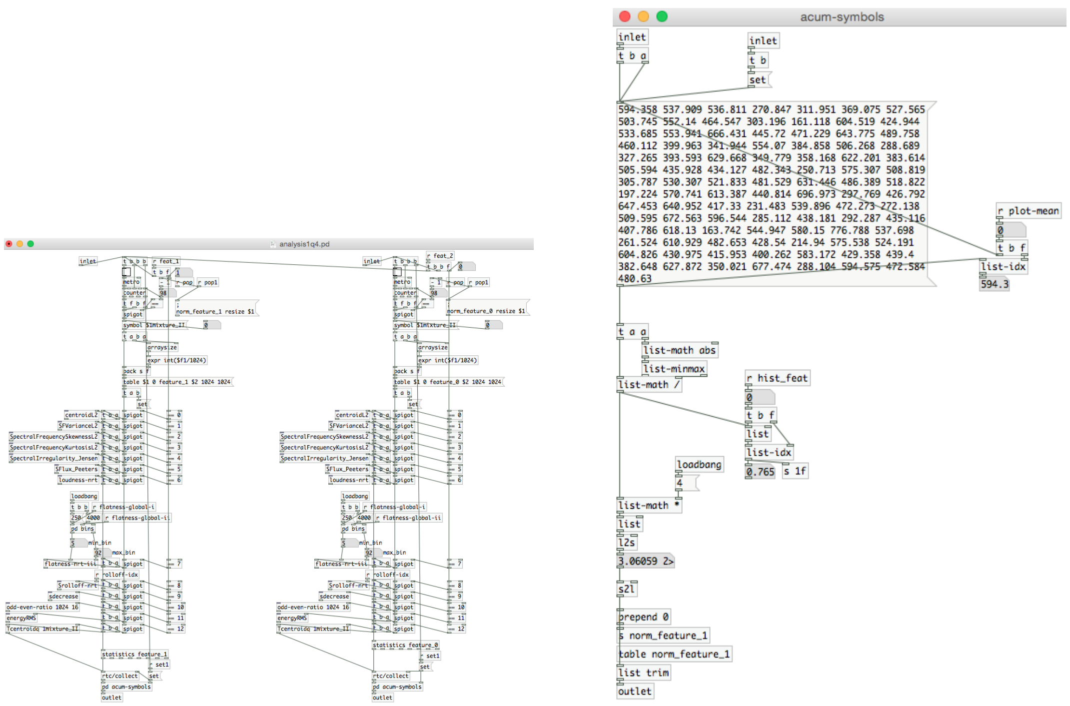
iii.6 Module 6 - Creation of the Sound Mixtures Space Exploration

this module, we have implemented a graphical user interface for the interaction, exploitation and selection of the sound mixtures. It was used sound mixtures using the GEM (*Graphics Environment for Multimedia*) library. The graphical *SSC* interface enables the visualization of four pairs of audio features and allows up to listening to the sound mixtures arranged on the GUI. Figure 7 presents the patch of the sound mixtures search and the four bi-dimensional graphic visualization. The first space is represented by yellow dots. The second space is represented by green dots. The third space is represented by the purple dots. Finally, the fourth space is represented by red dots.

iii.7 Module 7 - Selection of Sound Mixtures and Transcriptions

Module 7 controls the system output formats and there are two specific formats: a) audio file *.aif* and b) music score that is performed by an external PD object called *notes* developed by *Waverly Labs*, at *New York University - NYU*[5]. According to the description of *notes* the external object for Pure Data was conceived as an aid for computer assisted composition (CAC), generative music,

[5]For more information, visit: `http://nyu-waverlylabs.org/notes/`.



(a) (b)

Figure 6: *Figure of the Module 5 which performs the analysis of Sound Mixtures. The collected data is extracted by the audio features (Figure 6a). Figure 6b is the sub-module that calculates the mean of the collected data.*

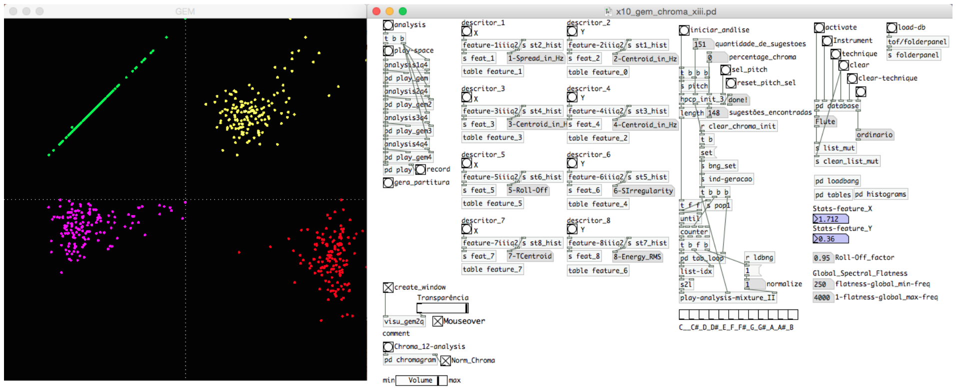


Figure 7: *Illustration of the Module 6 in which the user can interact with the sound mixtures in the exploitation space. In this module the user can hear the sound mixtures.*

and other places where symbolic music notation might be useful. This object interprets the data collected from the PD environment and converts them into a musical graphical notation in *Lilypond* format. The symbolic data that will be converted into musical notation must be configured in the particular syntax of the *Lilypond*. The module that interprets the symbolic data on musical transcription is called the *score-ssc1.pd*. Moreover, this module was not designed to produce final scores although this is conceivable. The composer often goes to lilypond and edit, copy, combine and modify scores in various ways.

There is the object *inst* that receives data such as 'musical instrument', 'musical pitch', 'dynamic' and 'instrumental technique'. Each musical instrument has its own object *inst*. In general, the algorithm receives a message with musical symbolic data and the object *inst* sends each information for its specific sub-module. The sub-module interprets the specific data and converts it in the *Lilypond* syntax. The next step creates a single message with all the information that will be interpreted by the *notes*. The diagram in Figure 8 summarizes all the steps of the musical information.

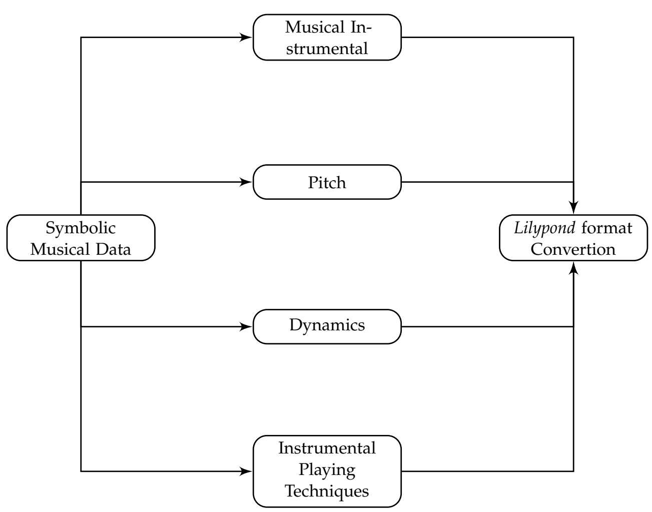
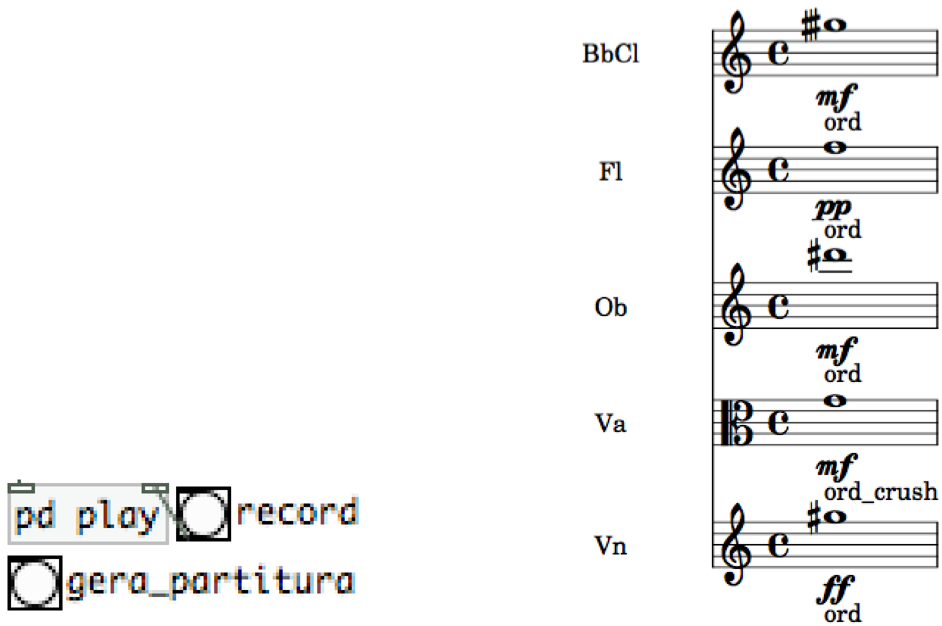


Figure 8: *Diagram Blocks for the musical information, convertion in* Lilypond *format.*



(a) (b)

Figure 9: *Figure of Module 7, which selects the sound mixture and stores it in audio format and in musical notation format in* lilypond. *Figure 9a is the* patch *interaction with the module 7. Figure 9b illustrates the score of a given sound mixture.*

In the current version of *SSC*, there is no temporal information for the orchestral sonorities. Each interaction will produce only an orchestral setting with previously established duration. Figure 9a illustrates the *patch* to store sound mixtures, in *.aif* format or in music sheet format, in *lilypond*. Figure 9b, represents an example of the score of a sound mixture.

iii.8 *Sound Shizuku Compostion - SSC* General Architecture

In the *SSC* system the orchestral possibilities result from the interaction of the analysis of audio descriptors with their potential semantic correlates. Timbre has several perceptual characteristics that may be intrinsically associated or orthogonally different. The sound analysis tools describe certain aspects that can highlight one or more specific characteristics related to the subjective attributes of timbre perception. Figure 10 illustrates the general outline for the orchestration computer-aided orchestration architecture.

III. Practical Applications

The system for supporting the compositional planning presented here focus on how musical orchestration connects two distinct universes *a)* instrumental extended techniques and *b)* computational tools to analyze and statistically describe the spectral content of the material generated by these techniques. Therefore, we developed a method to help the composer to relate: *a)* the high-level descriptions or symbolic data, called 'sonority' with *b)* the specific modes of extended playing techniques. Next we present three compositional that was created with the system, briefly.

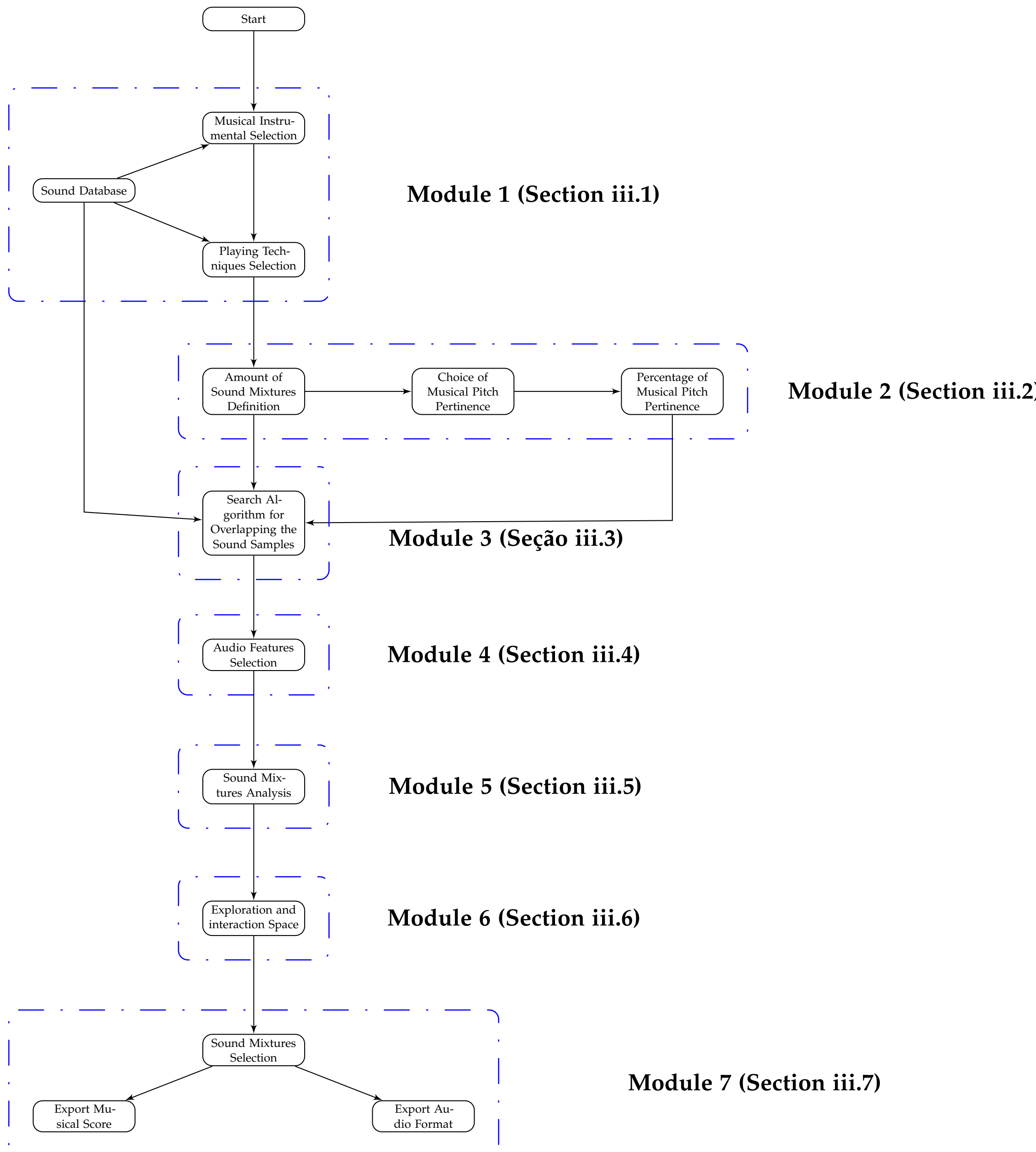


Figure 10: Sound Shizuku Composition - SSC *General Architecture.*

In the particular case of *Lana Tai*, the methodology expounded on the construction of 'Sound Mixtures', as discussed in Section II, which were anchored in two audio features: spectral chroma and spectral centroid. In *Lana Tai* the audio features were related to two contrasting ideas: *a)* opacity and *b)* brightness. The main ideas about the compositional planning can be found in [35, 33, 34].

The work *The oil, the moon and the river* was anchored in three audio features: Loudness, Spectral Irregularity and Spectral Chroma. The compositional planning consisted of contrasting sonorities called velvety and rough and the variation of their intensity in different dynamic levels. According to the analysis from the spectral irregularity, we find that the different playing techniques alter the timbre perception of each analyzed sound. Instrumental techniques which are characterized by instrumental noise insertion tend to relate to rough and ridged sonorities. Conversely, for velvety and smooth sounds we used certain instrumental techniques to result in clean and clear sound like *whistle tones*, on flutes. In the analysis using Spectral Chroma, we find the polarization of musical pitches in which we have established the basis of the melodic structure of the work. Published works for the analysis of the composition can be found in [36].

Finally in *Labori Ruinae* we used audio descriptors to produce gradual timbre transformations. Such analysis was anchored in a vector consisting of a set of six audio features. The formal structure of the work relates to the spectral transformation of five pairs of sonorities. Each sonority has been described by a vector with six audio descriptors. We interpolated each pair of sound from its degree of dissimilarity, in ascending order. We began to work with the pair of sonorities with lower dissimilarity index. Consequently, the work ends with the pair of the higher rate.

IV. Final Considerations

This article discussed a system to work as a new strategy on composition and orchestration within the vast domain of sounds produced by extended playing techniques. The research enabled the formal dialogue between analysis, audio descriptors with the conceptual, aesthetic and subjectiveness providing to the composer a tool to be applied into the process of musical composition. We presented the general architecture of the computer system and how aid to orchestration is done. In this architecture, we introduced five stages concerning to the creative process: *a)* defines the timbre characteristics to be exploited through the audio features. This step will define the aspects and timbre characteristics which will be worked compositionally; *b)* establishes the remarks within the space of characteristics, known as 'Referential Remarks'; *c)* conducts experiments in instrumental mixtures, known as 'Sound Mixtures', via orchestration of audio samples of several playing techniques. These configurations were built from a sound database of various instrumental playing techniques; *d)* defines the orchestral settings weighted by the particular preferences of the composer. This procedure ensures the effective participation of the composer in the final result of his own musical compositional; finally *e)* stores the sound mixture selected by the composer in musical notation and in audio format.

We introduced the audio descriptors used in our analysis with a computer environment. In total there are fifteen audio descriptors available and our perspective is associated with *SSC* focuses on improving and refining the algorithm analysis and the overlapping audio samples using techniques and tools of computer music and other computer models.

Moreover, we intend to publish other results obtained with the current version of *SSC* and also further advance the stage of the system. One of our goals is to expand the sound database by adding more audio samples. Another issue that we will address is to study correlations between orchestral sonorities and text descriptions of timbre characteristics with the affective/emotional states that may be induced or evoked by them.

V. Acknowledgments

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